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EVALUATION OF CI ENGINE PERFORMANCE AND EMISSIONFUELLED BY DIESEL-MOSAMBI PEEL PYRO OIL BLENDED WITH COPPER OXIDE NANOPARTICLES

K. VENKATESAN[1] & S. SATHYARAJ[2]

[1]*Associate Professor Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India*

[2]*Assistant Professor Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India*

ABSTRACT

The day by day increase in the emission of pollutants into the environment coming from road transport and rail way transports, and depletion of natural resources and economic considerations are the main reasons for the development of alternative fuels to power internal combustion engines. To boost the engine performance, copper oxide nano particles were doped along with mosambipeel pyro oil–diesel fuel blend as additive. Diesel engine's performance and emission characteristics were studied for 20%, 40%, 60%, 80% and 100% of the maximum power output with the fixed engine speed of 1500 rpm mosambipeel pyro oil with neat diesel. copper oxide nano particles were added in three difference concentrations as., 100, 200 and 300 ppm levels in all the three samples of mosambi peel pyro oil – diesel fuel blends to study their effects on engine performance. All bio-oil properties were studied made on the pyro oil, called as MDC10 (10%MPPO+100PPMCuO+ 90D), MDC20 (20%MPPO+200PPMCuO+80%D) and MDC30 (30% MPPO + 300PPM CuO+ 70% D). Characteristics of a fuel for Diesel, MDC10, MDC20 and MDC30 were analyzed. The blending of pyrolysis oil and copper nano particles are by mixing of diesel fuel by volume. The flash point, fire point, viscosity, density of the oils was observed. The samples ofblended fuels were examined in a 1500 rpm single cylinder diesel engine for their performance as blended fuel. Engine test results showed that the performance for all MDC10, MDC20 and MDC30 related to diesel fuel. At the maximum power output, the brake thermal efficiency was found as 31.5% respectivelywith MDC10, and where as, it was 30.0% with diesel fuel. There is a slight reduction for the smoke, and NOx emissions, HC and CO emission slightly reduced the MDC10,as fuel compared to diesel fuel at all power outputs.

KEYWORDS: Mosambi Peel Pyro Oil, Copper Oxide Nano Particle, Diesel Engine, Engine Performance & Exhaust Emission

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Original Article

INTRODUCTION

The large increase in automobile and industry, depletion of fossil fuel reserves and increasing the oil price in recent years has resulted in great demand for petroleum products. Indian annual condition for petroleum products is about 125 million metric tons, of which, the diesel consumption is approximately 50 million tones. The Indian states alone consume about 10 million barrels of oil per day, of which, about 60% is used in transportation, while the world's oil utilization amounts to 100 million barrels per everyday. The exhaust gases from the automobiles and industries affect human body and give rise to contagious diseases. In addition to considerable CO2 emissions, significant quantities of CO, HC, NOx, PM and other air toxins are emitted from automobiles in to the atmosphere, which leads to severe health difficulties. In recent years, adding nanoparticles to fluid fuels has been the focus of much test and outcomes have been reported. By means of using nanoparticles, with a high surface area to volume ratio can considerably increase contact between the fuel and oxidizer. In addition, nanoparticles a effects the time scale of chemical reactions, and as a result, the ignition delay time will decrease(2).The studies cited have shown that blended mosambi pyro oil fuels and nanoparticles promote fuel combustion. To our knowledge, attractive nanoparticles have not been used before. So in this study, a copper oxide nano particle is added to diesel fuel, to explore the effects on engine performance and exhaust emissions of a diesel engine.

PYROLYSIS SET UP AND EXPERIMENTS PROCEDURE

The reactor is made of steel material placed on the ground with high temperature meter. The outlet of the reactor is straight connected to the counter flow condenser using a stainless steel tube, which can withstand high temperature. Another one of inlet is connected to the reactor from the nitrogen cylinder. The condenser is firmly connected with the aid of alloy gasket. The flow of water is directed against to the direction of Pyrolysis gases. In this Pyrolysis apparatus, chipped mosambi peel material is full in the reactor initially, and then reactor has closed with the give hold to of bolt. Here, gasket was worn to prevent leakage. Then, supply nitrogen gas from the cylinder to reactor for the time period of 2 to 3 min, subsequent to its close. Switch on the electrical supply, initially set the temperature up to 550°C in the temperature controller. For condenser, water is supplied from inlet to outlet. Gases are collected in the cylinder. Finally, note the time taken to reach the temperature up to 550°C. Cooling time of the reactor is 10 to 11 hours. Finally, we have collected the Pyrolysis oil, char and syngases.

Figure 1: Pyrolysis Setup

Fuel Formulation

Pyro oil can be prepared with stable and homogeneous suspension of copper oxide in base diesel and mosambi pyro oil was made using ultrasonication for 20 minutes and magnetic starrer 1000 rpm speed for 20 minutes. Composition of the fuel was nanoparticles of 0.35wt%, and rest diesel. Physical properties of the nanofuel are given in Table 1. For preparing them,MDC10 (10%MPPO+100PPM+ 90D), MDC20 (20%MPPO+200PPM+80%D) and MDC30 (30% MPPO + 300PPM + 70% D)were taken in a container. Stable oil preparation may be obtained by stirring the mixture for 20 minutes, and the stability of the homogeneous mixture was found as stable for six month. Above 30%, blending fuel not stable long time. Table 2 shows that, for fuel properties of nana pyro oil blend. All properties of nano pyro fuel blends are near than that of diesel fuel.

Figure 2: Fuel Preparation

Figure 3: Nano Pyro Fuel Blends

Table1: Physical Properties of Nano-Particles and Nomenclature of Selected Nanofuels

Metal	Cu
Particle size (nm)	<50
Atomic mass (g/mol)	79.55
Bulk density (g/cm3)	6.31
Metal melting point (C)	1201
Oxide formed	CuO
Oxide melting point (C)	2000

Table 2: Physical Properties of Nano-Particles Blended Fuels

Fuels	Density(kj/kg)	Viscosity(cst)	Calorific Value(kJ)	Flash Point	Fire Point
Diesel	836	3.45	43500	52	58
MCD10	846	3.56	43800	50	55
MCD20	912	4.5	42500	58	63
MCD30	948	4.9	41700	61	65

Engine Test Setup

Engine performance were calculated on a single-cylinder, four-stroke, water cooled at a stable speed 1500 rpm direct injection diesel engine. In order to find out the engine torque, test engine was attached to water cooled eddy current type dynamometer. The setup also comprised piezo combustion instruments analyzer for combustion pressure and crank-angle measurements that were interpret to produce Pθ diagrams. The stand-alone panel box of test setup consist of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. The engine tests were performed initially with clean diesel at fully throttled and no load conditions, and then nano pyro fuel was fed through a separate fuel feed line. Prior to run the engine with a new fuel, it was allowed to run for adequate time to consume remaining fuel from the preceding experiment. The entire experiments were carried out by varying the loads at a constant speed of 1500 rpm to evaluate the performance characteristics such as specific fuel consumption, brake power and exhaust gas temperature and brake thermal efficiency. Engine performance analysis software was used for online performance evaluation. More than three run of tests were performed under the identical conditions, and the repeatability of all result parameters was found. The emission characteristics of Smoke, CO, NOx and HC were measured using an Exhaust Gas Analyzer.

Figure 4: Photograph View of Engine Setup

Table 3: Specification of the Diesel Engine

No. of Cylinders	01
Bore	87.5mm
Stroke	110mm
Compression ratio	17.5:1
Rated power	4.4 KW
Injection pressure	160 bar
Rated speed	1500 rpm
Injection timing	27˚ BTDC
Orifice diameter	13.6mm

Uncertainty Analysis

For the entire experimental outcomes, care was taken to free them from posse’s errors. These errors are of systemic and random nature. The systemic errors were corrected by calibration method. The uncertainties in the results due to random errors are obtained statistically. Uncertainties in the measured parameters from the experiments were estimated with confidence limits of ± 2σ (95.5% of measured data lie within the limits of ± 2σ around the mean). The percentage uncertainty in the measured parameter was estimated using the equation

$$\Delta x_i\,(\%) = \frac{2\sigma x_i}{\bar{x}_i} \times 100$$

Where, $\bar{x}$ - Mean of measured quantity

σ - Standard Deviation

In order to contain reasonable limits of uncertainty for the computed values obtained from the measured parameters, the uncertainties were evaluate based on Kline and Mc. Clintock method[3].The uncertainties for some of the measured and compute quantities from the experiment are shown in Table 3.

Table 3: Uncertainty in Engine Parameters

Parameters	Uncertainty Analysis (%)
Engine speed	1500±1.2%(rpm)
Brake power	2.5±1.2%(kW)
Fuel flow rate	0.52±2.0%(g/Sec)
Smoke Opacity	40±1.3%(%)
Oxides of Nitrogen	405±1.0%(ppm)
Hydrocarbon	100±0.8%(ppm)
Carbon Monoxide	0.12±0.8 % (%)

RESULTS AND DISCUSSIONS

Combustion Characteristics

Figure 5shows that variation in cylinder pressure with change in crank angle for nano pyro fuel and diesel. The peak cylinder pressures at full load condition for the nano pyro fuel and diesel were around 69, 67, 58 and 43 bars, respectively. Decline in peak cylinder pressures were noted down with nanofuel as compared to diesel. The nanofuel reduces the chemical setback period that exerts a great influence on the combustion phenomena of Compression Ignition engine as well as on the rate of pressure rise, because the longer the delay, more rapid and higher pressure rise occur. Decline in the peak pressure is accredited to the fact that both physical and chemical delays decrease with addition of nanoparticles. Hence, the improved ignition properties of energetic CuO nanoparticles initiate early combustion, and thereby reduce peak pressures. It is seen that MCD10, MCD20 and MCD30 followed the trend similar to diesel fuel. MCD20 and MCD30 resulted in lower peak pressure as compared to neat diesel. MCD10 increase the cylinder peak pressure.

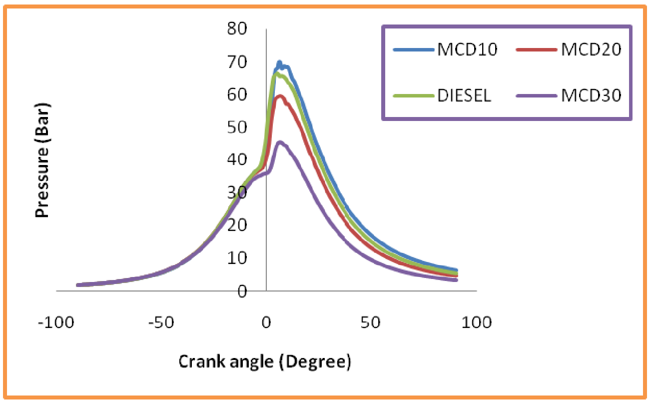

Figure 5: Variation of Cylinder Pressure with Crank Angle

Performance Parameters

The difference in brake thermal efficiency with brake power for diesel, MCD10, MCD20 and MCD30can be seen in Figure 6. There is an increase in brake thermal efficiency with all the tested fuels with increase in engine power. It is seen that neat MCD10 with 21% oxygen in the air resulted in higher brake thermal efficiency as compared to neat diesel at all power outputs. The maximum brake thermal efficiency was found as 31% at the maximum power output of 4.4 kW, where as it was 30.5% with neat diesel. The MCD20 and MCD30shows that reduction in brake thermal efficiency is the results of poor combustion of the injected blended nano pyro oil due to its high viscosity, density and poor volatility [6].

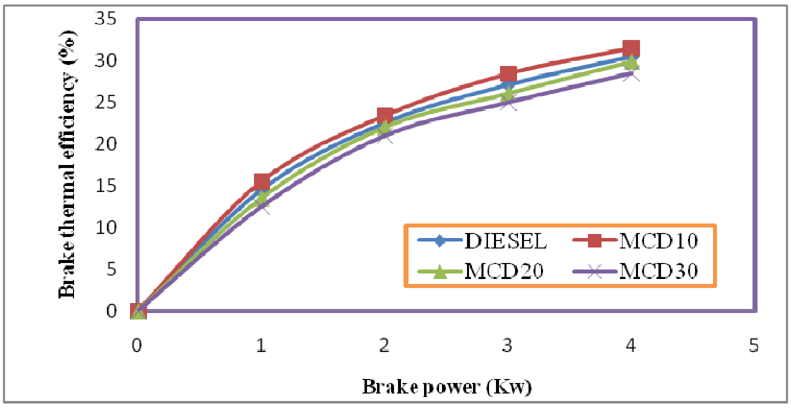

Figure 6: Variation of Brake Thermal Efficiency with Brake Power

It is seen that there is an improvement in brake thermal efficiency with CuOnano fluids at all power outputs. At the maximum power output of 4.4 kW the maximum brake thermal efficiency was as 29% and 28.5 % respectively. The improvement in brake thermal efficiency with CuOnano pyro oil can be explained by the changes occurring in the combustion process of the MCD, due to the availability of more oxygen in the combustion chamber, which resulted in complete combustion of the MCD. It was suggested that retarding the timing could compensate the heat loss. However, at low power outputs, the brake thermal efficiency was not affected.

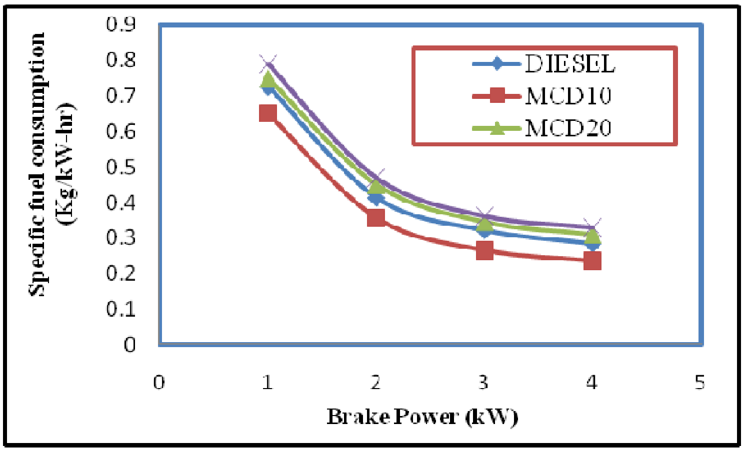

Figure 7: Variation of Specific Fuel Consumption with Brake Power

For all MCD10, MCD20 and MCD30fuels, the SFC decreases with an increase in the engine load, while the BTE increases with the increase in engine load for all MCD fuels. This is clear from the detail that the increase in fuel required to operate the engine is less than the increase in brake power at higher loads, adding a CuOnano particle to diesel fuel will decrease the SFC. The decrease in SFC can be due to the positive effects of nanoparticles on physical properties of fuel [6], and also reduction of the ignition delay time, which lead to more complete combustion [7]. In addition, it can be due to effects of nanoparticles on fuel propagation in the combustion chamber. On the other hand, nanoparticles added to diesel fuel increase the blend momentum and, consequently, the diffusion depth in the cylinder.

Figure 8 shows the increase in Exhaust gas Temperatures of engine with load. It could be subject from the figure that Exhaust gas Temperatures increases with load for both diesel as well as nano pyro fuel, clearly due to increase in the combustion temperature. The remains of nano pyro fuel droplets which are formed due to microexplosion of primary droplet generate secondary automation of local flames, which further increase combustion temperature. Rise in temperature at full load conditions has been observed as 10% for nano pyro fuel, as compared to diesel.

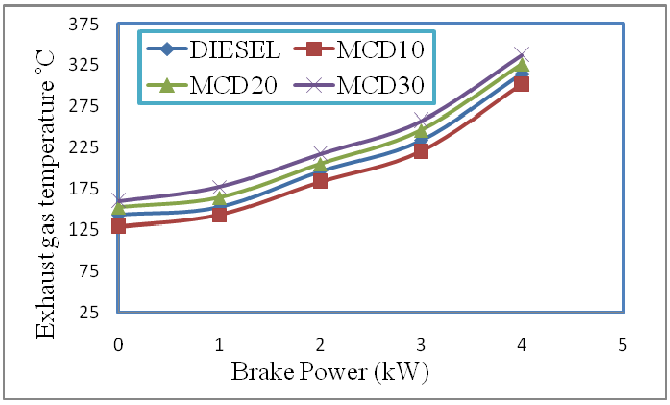

Figure 8: Variation of Exhaust Gas Temperature with Brake Power

Emission Parameters

The smoke emission resulted from combustion of diesel, MCD with CuO nano particle is depicted in the Figure 9. Smoke opacity increased with increase in engine power with all the MCD10, MCD20 and MCD30 fuels. The increment in smoke emission with engine power is due to the amount of fuel injected, to be more with the raise in power. It is seen that, smoke level was lower at all power outputs with MCD CuO nanoparticle, as compared to neat diesel.

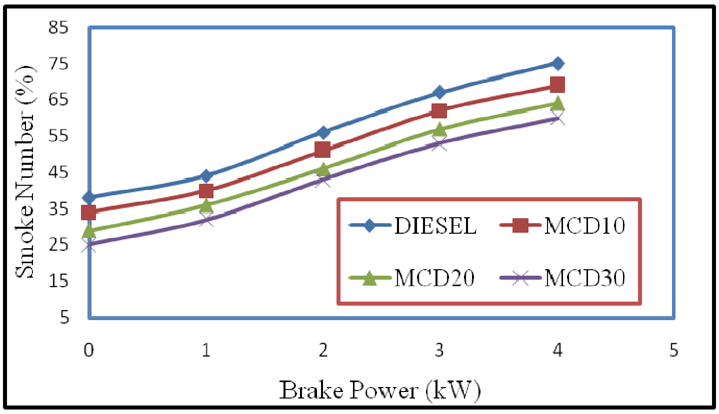

Figure 9: Variation of Smoke Number with Brake Power

However, considerable reduction in smoke emission was noted with MCD in oxygen content of pyro oil engine operation at all power outputs. The main reason for the reduction in smoke emission with the oxygen content of fuel mixture is due to the improved mixture preparation, which reduced the restricted fuel rich regions present in the combustion chamber. Due to the oxygen content of pyro oil combustion was complete, and hence the smoke emission. At the maximum power output, the smoke emission was noted as 69%, 64% and 60% respectively, with MCD10, MCD20 and MCD30 fuels.

The oxides of nitrogen emission of the engine operating on diesel, MCD10, MCD20 and MCD30 are NOx emission increased with increase in engine power for all the fuels. This is due to the raise in peak cycle temperature resulted from more energy release on account of more fuel burnt. MCD10 resulted in lower NOx emission as compared to neat diesel at all power outputs. At peak power out, the NOx emission was found as 426 ppm with MCD10 and 458 ppm with diesel fuel. The reduction in NOx emission with MCD10 was due to the complete combustion of fuel due to high calorific value of the fuel and low viscosity and density of the blended fuel. The increase in NOx concentration in the exhaust can be explained very well by the increase in bulk cycle temperature, immediately after combustion. It could be argued that at the higher loads, burning temperatures in the combustion chamber increases with load and facilitate NOx emissions, according to Zeldovich thermal mechanism [8]. An increase of 5% was observed in NOx emission with MCD 20 and MCD30 nanofuel, as compared to diesel fuel.

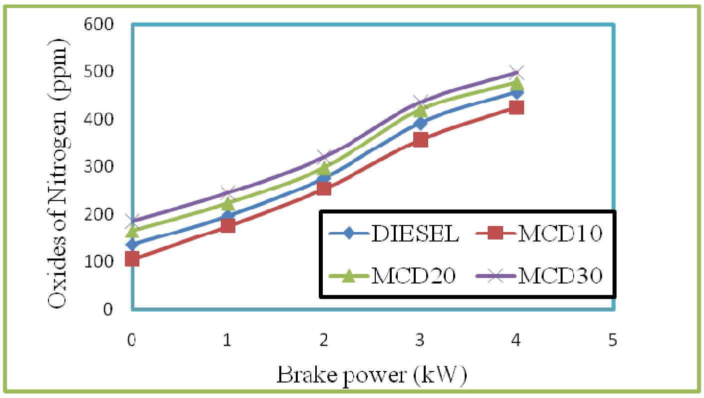

Figure 10: Variation of Oxides of Nitrogen with Brake Power

The variation of HC emitted from diesel, MCD10, MCD20 and MCD30is shown in Figure 11. The HC emission increased with increase in engine power, for neat diesel and MCD10, MCD20 and MCD30. MCD10 emitted at atmospheric oxygen concentration resulted in less hydrocarbon emissions at all operating conditions, as compared to neat diesel fuel. At the maximum power output, the hydrocarbon emission was found as 92 ppm with neat diesel and 85 ppm with MCD10. The main reason for the lower hydrocarbon is due to the result of complete combustion of MCD10. The low viscosity and high volatility of MCD10resulted in fast combustion and reduced the hydrocarbon emissions. Hydrocarbon emission was reduced in case of neat biofuel, compared to diesel operation due to fuel bound oxygen, which improves the combustion and reduces the fuel rich zone [9]. HC is slightly higher at peak load for MCD20 and MCD30, this may be credited to the fuel spray that does not propagate deeper into the combustion chamber, and gaseous hydrocarbons remain along the cylinder wall and the crevice volume, left unburned and micro explosion of fuel[10].

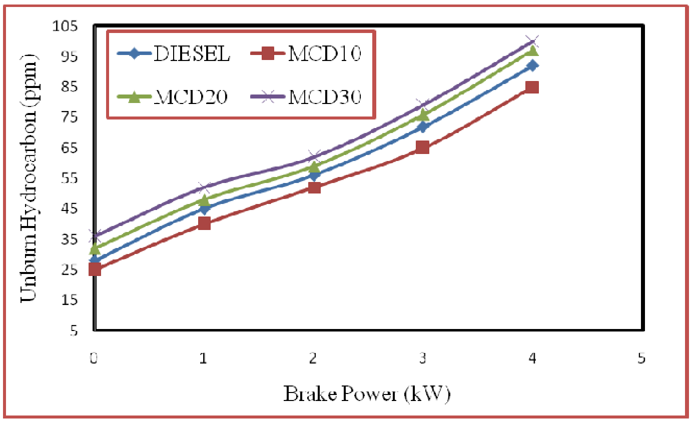

Figure 11: Variation of Unburn Hydrocarbon with Brake Power

Figure 12 shows the variation of carbon monoxide emission with diesel, MCD10, MCD20 and MCD30. CO emission increased with increase in engine power for neat diesel and MCD10, MCD20 and MCD30. The increment in CO with raise in engine power is due to the amount of injected fuel to be more, which resulted in fuel richness. MCD20 and MCD30 resulted in higher carbon monoxide emissions, as compared to diesel at all power outputs. It can be explained that MCD20 and MCD30 due to its poor energy content, resulted in more fuel to be injected for the same power output. This behavior has led to fuel richness and resulted in more carbon monoxide emissions. At the maximum power output, the carbon monoxide emission was found as 0.12% with MCD10 for the atmospheric condition and 0.13% with diesel. As explained already, the enrichment in oxygen helped in complete oxidation of the carbon present in the injected MCD20 and MCD30, and resulted in complete combustion, hence the trend.

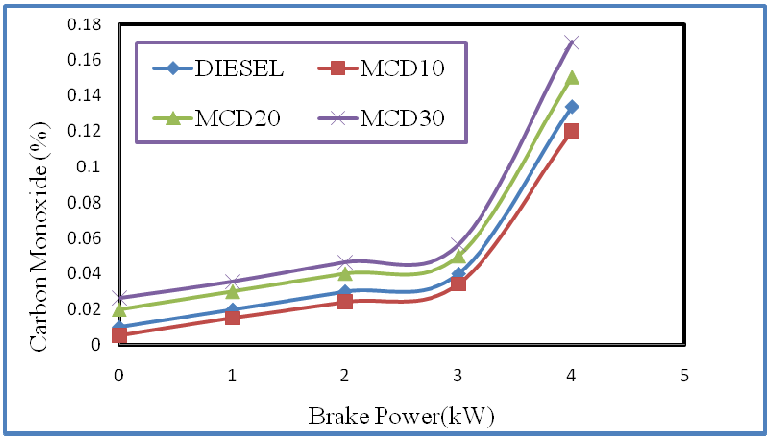

Figure 12: Variation of Carbon Monoxide with Brake Power

Figure 13 indicates the trend of heat release rate using MCD10, MCD20 and MCD3 as fuel at the maximum power output. The heat release rate was analyzed by making the first law analysis of the average pressure versus crank angle variations [11]. The initial drop in heat release rate in Figure 13 reflected the temperature drop due to vaporization of the injected fuels. It is seen that MCD20 and MCD30 resulted in reduced premixed combustion phase.

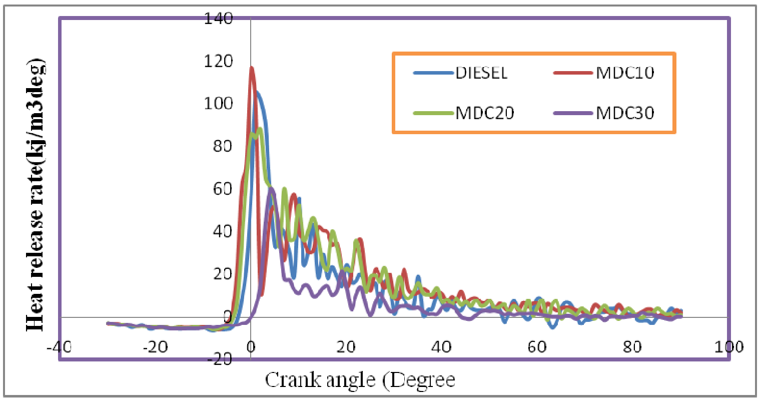

Figure 13: Variation of Heat Release Rate with Different Nano Pyro Fuels

This is due to high viscosity and poor volatility of MCD, as previously explained. The diffusion combustion phase was found as significant, due to slow burning characteristics of the MCD20 and MCD30. It is clearly seen that, MDC10 and diesel fuel resulted in maximum rate of heat release and the fraction of fuel burned during the primary period of time, whereas the premixed combustion rate was lower and the diffusion combustion rate was slightly higher for MCD20 and MCD30as compared to MCD10. There was a delay in start of ignition withMCD20, and it was increased further with MCD30. The reduction in cetane number caused the ignition delay to prolong with the nano particle of MCD, as compared to diesel fuel. The reduction in premixed combustion rate of the nano particle of MCD20 and MCD30 can be explained by the high viscosity and density of the fuels, which resulted in combustion to be more in the diffusion combustion phase.

CONCLUSIONS

The MPPO oil (both obtained by heating between 150°C and 550°C and on fast pyrolysis method) has fuel like properties worth a detail study. The maximum oil yields of about 60% (~ 25–30% obtained up to 350°C plus 20% obtained on pyrolysis) have been achieved. A temperature of 550°C for pyrolysis is optimum yielding the maximum percentage of oil.

Influence of Nano particle on performance, emissions and combustion characteristics of a diesel engine fuelled with MCD (MPPO+ CuO+ D) was studied, experimentally. The following conclusions are made based on the findings.

The brake thermal efficiency was found as 31.0% with MCD10, whereas, it was 30.5% with diesel at the maximum power output of 4.4 kW. The smoke emission was noted as 75% with diesel and 69% with MCD10 at the maximum power output.

The SEC for MCD10 is 0.235kg/kW-hr, and for diesel 0.284kg/kW-hr at full load. The SEC increases by about 0.06% with MCD20 and MCD30.

The EGT is lower for MCD10 compared to that of diesel at full load. MCD20 and MCD30 are higher than diesel fuel.

Carbon monoxide is decreased by about 10% for MCD10 compared to that of diesel, at full load.

The NO emission is less than by about 23% for MCD10, compared to diesel, at full load condition.

Smoke opacity is lowered by about 25% for MCD10 compared to that of diesel, at full load operation.

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